FUNCTIONAL 3-D: OPTIMIZED LATTICE PARTITIONING OF SOLID 3-D MODELS TO CONTROL MECHANICAL PROPERTIES FOR ADDITIVE MANUFACTURING

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application Ser. No. 62/220,427 filed Sep. 18, 2015, which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] The present disclosure relates to the optimized lattice partitioning of solid 3-D models for additive manufacturing to control mechanical properties. The technology described herein is particularly well-suited for, but not limited to, additive manufacturing based on computer aided designed-based models.

BACKGROUND

[0003] Recent advances and price drops in additive manufacturing technology have made three-dimensional (3-D) printers more affordable than ever before. Although their wide-scale adoption of such printers is expanding day by day, a key challenge in 3-D printing technology is using a single fabrication material with prefixed material properties which limits the applicability of additive manufacturing to a small set of commercial products. There is a need and desire to perform 3-D printing with a mix of materials such that different portions of the object being printed may have different functional properties. However, conventional techniques are generally limited in how materials can be mixed during additive manufacturing. Moreover, even where mixing is permitted, it is generally done in a very rough manner that does not result in smooth transitions between the different types of materials being used for printing.

SUMMARY

[0004] Embodiments of the present invention address and overcome one or more of the above shortcomings and drawbacks, by providing methods, systems, and apparatuses related to the optimized lattice partitioning of solid 3-D models for additive manufacturing to control mechanical properties. More specifically, the techniques described herein address the challenge of fabricating 3-D printed objects with desired functional properties such as thermal and structural properties. Instead of focusing on a single material property, a pipeline is utilized that can be useful for a wide variety of functional properties. The disclosed techniques use a data-driven approach and capability of integrating multi-physics functionalities while preserving a smooth functional transition.

[0005] A computer-implemented method of optimized lattice partitioning of solid 3-D models for additive manufacturing includes a computer receiving a 3-D model of an object to be printed (e.g., a computer-aided design (CAD) model) and functional specifications indicating desired mechanical properties for portions of the object. The computer generates a plurality of lattice template structures based on the 3-D model and a uniform grid structure of an internal surface of the object. The computer determines material behaviors for each of the lattice template structures using the functional specifications. The material behaviors for each of the plurality of lattice template structures may be determined, for example, by simulating the material behaviors of each lattice template structure at object scale with periodic boundary conditions. Then, the computer assigns the lattice template structures to locations in the uniform grid structure based on the material behaviors of the lattice template structures, thereby yielding a printable lattice. In some embodiments, the lattice template structures are assigned to location in the uniform grid structure according to an optimization problem. This optimization problem may be solved, for example, using a graph and tree search technique such as branch and bound.

[0006] Various techniques may be used for generating the lattice template structures used in the aforementioned method. In some embodiments, the lattice template structures are generated using implicit volumetric representations of the object such as, for example, voxel occupancy grids or level-sets of 3D scalar fields.

[0007] According to another aspect of the present invention, an article of manufacture for optimized lattice partitioning of solid 3-D models for additive manufacturing comprises a non-transitory, tangible computer-readable medium. This medium holds computer-executable instructions for performing a method comprising generating a plurality of lattice template structures based on a user-specified 3-D model of an object to be printed and generating a uniform grid structure of an internal surface of the object. The performed method may further include determining material behaviors for each of the plurality of lattice template structures using user-specified functional specifications indicating desired mechanical properties for portions of the object and assigning the plurality of lattice template structures to locations in the uniform grid structure based on the material behaviors of the lattice template structures, thereby yielding a printable lattice.

[0008] According to other embodiments, a system partitioning a model to facilitate printing of the model on a three-dimensional printer comprises one or more 3-D printers, one or more processors, and a non-transitory, computer-readable storage medium in operable communication with the processors. The computer-readable storage medium comprises one or more programming instructions that, when executed, cause the processors to generate a plurality of lattice template structures based on a user-specified 3-D model of an object, determine material behaviors for each of the lattice template structures using user-specified functional specifications, and generate a printable lattice by assigning the lattice template structures to locations in a uniform grid structure based on material behaviors of the lattice template structures. The 3-D printers are configured to print representations of the object based on the printable lattice. In some embodiments, the aforementioned system further comprises a parallel processing platform comprising the one or more processors and configured to determine the material behaviors for two or more of the lattice template structures in parallel.

[0009] Additional features and advantages of the invention will be made apparent from the following detailed description of illustrative embodiments that proceeds with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The foregoing and other aspects of the present invention are best understood from the following detailed